Journal of the Arkansas Academy of Science

Volume 53 Article 19

1999

Morphometry and Limnology of Ferguson Lake, Saline County, Arkansas

John D. Rickett
University of Arkansas at Little Rock

E. P. (Perk) Floyd
U.S. Public Health Service

Morphometry and Limnology of Ferguson Lake, Saline County, Arkansas

John D. Rickett
Biology Department
University of Arkansas at Little Rock
Little Rock, AR 72204

E.P. (Perk) Floyd
U.S. Public Health Service (ret.)
2423 E. Woodson Lateral, No. 35
Hensley, AR 72065

Abstract

To more fully understand Ferguson Lake as an ecosystem and eventually relate its water quality and production potential to fisheries management, several limnological variables were sampled monthly from April 1997 through March 1999. Vertical profiles of temperature and dissolved oxygen were recorded, and water samples from 0.5 m. depth were tested for turbidity, pH, total alkalinity, total hardness, ortho-phosphate, nitrate-nitrogen, sulfate, iron and specific conductance. Evaporation rate experiments, spillway discharge and rainfall records were used to estimate lake hydrology. Depth transects on the lake and USGS topographic maps were used to measure and calculate morphometric and watershed features.

The lake is essentially the deep end of a swamp (d_{max}= 4.27 m.; d_{mean} =1.92 m.) which is dominated by a lowland hardwood species-pine mix. Numerous cypress (*Taxodium distichum*) and tupelo gum (*Nyssa aquatica*) trees stand in the uppermost one-third of the lake. The rapid deposition and slow decomposition of organic debris on the lake bottom are the primary contributors to the brown water, relatively low pH, and hypoxia in and near the sediments from May through November. There was no evidence of thermal stratification, and pH ranged between 6 and 7, except for brief periods of rapid photosynthesis during the summers. Alkalinity, hardness and specific conductance were quite low, compared to most natural waters in this region. Phosphate, nitrate and sulfur were also comparatively low, and iron was low except after rainfall events which resulted in fairly heavy runoff.

Introduction

Ferguson Lake is a privately-owned recreation lake located in eastern Saline County, Arkansas. The charter members of the newly-formed country club purchased the land from C.E. Ferguson, who had bought the land earlier from William Farrell. When a narrow-gauge, 25-mile railroad tram crossed the property (it crossed Clear Creek about 50 m. upstream of the current levee), Mr. Farrell built a state-of-the-art sawmill at Wrightsville and employed the railroad to transport logs to the mill. In the early 1900s Clear Creek was dammed to create a small impoundment associated with timber harvest, which was included in an enlargement project in 1920 by the construction of a second taller levee further downstream on Clear Creek (Rice and Rooker, n.d.). The second levee more than doubled the original area of the lake.

Large portions of the watershed are swampy and blanketed with a mix of pine and deciduous lowland tree species. Three smaller lakes (Sandy, Mary and Spring Lakes) are located on Clear Creek upstream from Ferguson Lake; each has limited adjacent housing development. The water in all four lakes is brownish, superficially indicating a significant loading of organic acids, low pH and slow nutrient turnover. Numerous local housing developments and a few small businesses are also located in the watershed.

Forty-three cabins and a lodge are located around the eastern and southern sides of Ferguson Lake. Seven cabins are permanently occupied whereas the others are used only for week-end getaways and short-term vacations. Additionally, numerous other visitors use various recreational resources that the lake and its environs offer. Angling is the foremost activity, and, understandably, concerns regarding angler satisfaction have periodically arisen. This project was begun to more fully understand the lake as an ecosystem and the roles played by its major components in the production of catchable fish.

Beasley and Wigley (1988) described the shallow end of Ferguson Lake as containing a dense stand of tupelo gum (*Nyssa aquatica*) and abundant fanwort (*Cabomba caroliniana*), bladderwort (*Utricularia* sp.), waterlily (*Nymphaea odorata*), watershield (*Brasenia schreberi*), and American lotus (*Nelumbo lutea*). They found no evidence of excessive sedimentation due to watershed runoff, and opined that the dense stand of tupelo gum trees probably rapidly slowed the water which contributed to quick deposition of sediments transported by tributaries. They also noticed a fairly rapid accumulation of leaf litter, primarily from the tupelo gum trees and connected local hypoxia to leaf decomposition.

Methods

Two stations were established on the lake (Fig. 1), and

22 data collecting trips were made between 29 April 1997 and 6 March 1999. Water quality variables (turbidity, pH, ortho-phosphate, nitrate-nitrogen, sulfate and iron) were measured with a HACH DR-EL portable spectrophotometer using reagents provided by Hach Chemical Company. Total alkalinity was determined with the BCG-MR titration method whereas total hardness was determined with the EDTA titration method using Eriochrome Black-T as an endpoint indicator (Standard Methods, 1985). Vertical temperature and dissolved oxygen profiles were measured with a YSI Model 51 Dissolved Oxygen Meter, and specific conductance was measured with a HACH Conductivity/TDS Meter. These data were statistically compared by Student's T-test with a dataset collected between 1979 and 1989 by Arkansas Power & Light (now Entergy Corporation) personnel. Duplicate samples of benthic organic detritus were taken at each station with a 6 X 6-inch Ekman grab. Overflow discharge was recorded by measuring the depth of flow over the spillway crest and its velocity with a General Oceanics Model 2031 impeller-type flowmeter. Evaporation rates were measured and, with overflow data, were related to the lake's volume. Watershed parameters and lake surface area were calculated from USGS topographic maps and aerial photos. Form factor and coefficient of compactness (formulae in Reid and Wood, 1976) were determined to estimate the proportion of any given rainfall event covering the entire watershed. Morphometric characteristics were calculated from a series of north-south depth transects.

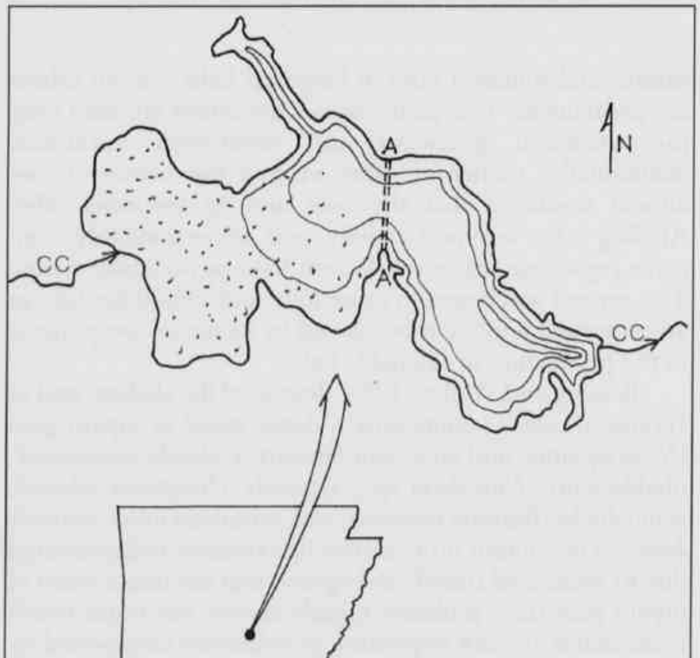

Fig. 1. Location of Ferguson Lake, Saline County, Arkansas. Stippling: swamp dominated by tupelo gum, *Nyssa aquatica* A-A': original dam from "high" point (A) to "low" point (A') CC: Clear Creek Depth contours: 1m intervals

Results and Discussion

Lake Morphometry and Watershed.--Ferguson Lake does not precisely fit the usual characterization of a "blackwater" habitat. Harper and Bolen (1995) describe a blackwater lake as one with waters stained dark brown with pH usually less than 5.5. In such a lake the pH doesn't appreciably affect the decomposition rate of organic materials. The water in Ferguson Lake was medium brown in color, and the pH readings usually ranged between 6 and 7. Brinson (1977) described an alluvial wetland/swamp habitat in North Carolina that appeared to be very similar with respect to pH, water color, and dominant watershed species to Ferguson Lake. He observed a "moderate" rate of leaf decomposition (faster than in a blackwater habitat).

Morphometric characteristics of Ferguson Lake and its watershed are given in Table 1. Much of the upper (shallower) half of the lake contains standing bald cypress (*Taxodium distichum)* and tupelo gum (*Nyssa aquatica*) at high density. These trees deposit a large amount of organic

Table 1. Morphometric characteristics of Ferguson Lake and watershed, Saline County, Arkansas

1. Area of lake proper	115.04 ha
2. Area of lake and adjacent swampy area	171.22 ha
3. Depth-maximum	4.27 m
4. Depth-mean	1.92 m
5. Volume	3.3×10^6 m^3
6. Shoreline length	10.235 km
7. Shoreline development	2.692
8. Normal pool elevation	74.4 m
9. Watershed area	58.56 km^2
10. Watershed axial length	11.27 km^2
11. Watershed mean width	5.39 km^2
12. Watershed form factor (ff)	0.479
13. Watershed coefficient of compactness (cc)	1.44
14. Watershed to lake area ratio	34.2:1
15. Watershed elevation range	74.4-115.8 m
16. Total area of other impoundments above Ferguson Lake	60.94 ha
17. Total creek channel length (incl. lakes) above Ferguson Lake	10.82 km
18. Total unimpounded channel length above Ferguson Lake	6.96 km
19. Mean channel sinuosity	1.308

material into the lake in addition to what is washed in from the watershed. The buildup of semi-decomposed matter on the bottom (heavier at station 2) indicates the deposition rate exceeds the decomposition rate. A cypress/gum-dominated swamp that is permanently inundated is usually considered oligotrophic (Horne and Goldman, 1994), that is, relatively few basic nutrients are available to be fed into the primary productivity process. In part, this slow release of nutrients is due to a mild hypoxia near and in the sediments during much of the summer. Lower pH levels may also inhibit decomposition. It has also been noted by Comer and Day (1991) that tupelo gum leaves decompose much slower than many other species of leaves (65% [by mass] of their experimental tupelo gum leaf packets remained in a Louisiana forested wetland after five months).

The shoreline is heavily vegetated with almost no bare soil at the water's edge, so erosion is slight, and the silt load in the water is low. The water is brown indicating high concentrations of tannic and humic acids. The intensity of the brown water color varies according to the discharge of Clear Creek - heavy runoff carries some silt which lightens the brown color.

Many types of activities occur in the watershed, but none are done on a large enough scale to alter the dominant impact of the lowland forest community on the lake. The watershed to lake area ratio of 34.2:1 would also lead us to expect the lake to be mostly controlled by the adjacent swamp and swamp-like character of the watershed. The relative lack of elevation change indicates rainfall runoff would proceed slowly, easily picking up a load of organic acids before it reaches any impoundment. The three smaller lakes upstream from Ferguson Lake probably trap some of the organics, but sufficient other watershed areas draining into Ferguson Lake directly still contribute much to its native water characteristics.

Of all geometric figures, a circle contains the maximum area for a given perimeter length. The form factor (FF) relates the axial watershed length to its mean width and was calculated as 0.479 (a circle would be 1). The coefficient of compactness (CC) relates the watershed perimeter to the circumference of a circle of the same area and was calculated as 1.44. Both values indicate the watershed shape is considerably different from a circle, thus for a given rainfall event, the total precipitation descending on the watershed area would be considerably less than if the watershed was a circle. If we relate the watershed area to the area of a circle whose circumference equals the watershed perimeter, the result is 0.482. This value could be used as the probability of any given rainfall event covering the entire watershed.

Hydrology.--Most of the soils in the watershed contain large amounts of semi-permeable clays, so infiltration of rainfall is slow. If the rain falls rapidly, much of it runs off but not rapidly because of the forested nature of the watershed, the heavy ground litter and the lack of significant slope. Evaporation rate trials were conducted near the shore of the lake through the months of May 1998 and February 1999. The mean rate for the entire lake was calculated to be 0.574 $ml/cm^2/day$ (6.6×10^3 m^3 per day for the lake) in May and 0.258 $ml/cm^2/day$ (3×10^3 m^3 per day for the lake) in February. The estimates represent 5.6 and 2.5 percent, respectively, of the lake volume.

Spillway discharge was zero or unmeasurably small from June through November 1998 and ranged between 0.07 and 2.54 m^3/s from December 1998 through March 1999, except a heavy rain in mid-September caused 0.044 m^3/s to overflow (Table 2).

Table 2. Spillway discharge (Q) at Ferguson Lake.

Date	Q(m^3/s)	Q(m^3/day)
27 Feb 98	1.19	102,816
30 Apr 98	0.07	6408
1 May 98	0.0064	553
2 Jul 98	0.0	0
31 Jul 98	0.0	0
20 Aug 98	0.0	0
17 Sep 98	0.044	3787
29 Oct 98	0.0	0
3 Dec 98	0.018	1555
4 Feb 99	2.54	219,594
6 Mar 99	0.052	4530

Physiochemical Characteristics.--Temperature (Fig. 2) exhibited the expected seasonal variations of a summer high of 36°C and winter low of 8°C. During the summer of 1997, the surface to bottom range was 35.5°C to 22.4°C (13.1°C difference) on 24 June and 33.2°C to 27.2°C (6.O°C difference) on 26 August. In 1998 the same temperature range was 34.9°C to 29.8°C (5.1°C difference top to bottom) on 2 July and 33.2°C to 30.5°C (2.7°C difference) on 31 July. For both years, the maximum surface temperature was recorded in June, whereas the maximum bottom temperature was recorded about a month later. The lake did not develop thermal stratification, although the mean top to bottom

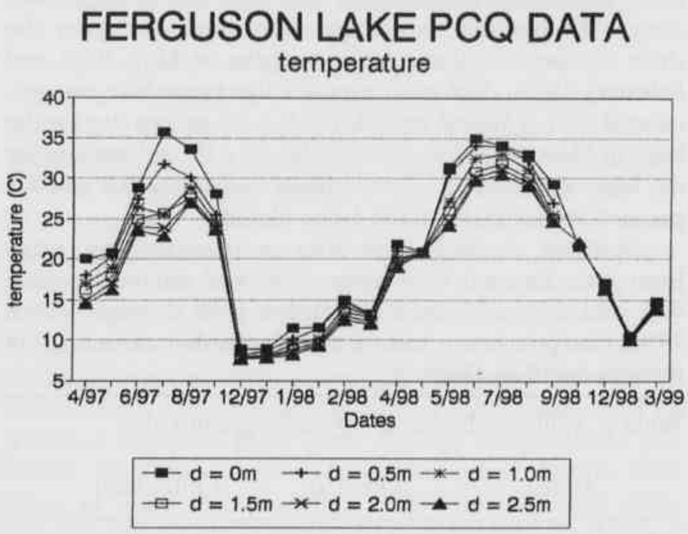

Fig. 2. Temperature profiles in Ferguson Lake, April 1997-March 1999.

range for the summer (May through September) was 7.2°C in 1997 and 4.6°C in 1998. The vertical profile of temperatures at all other times was more tightly clustered.

Dissolved oxygen (Fig. 3) also exhibited greater top to bottom spread in the summer than during other months. Water just above the bottom during both years became hypoxic. On 24 June 1997, the top to bottom range was 9.0 to 0.4 mg/l (8.6 mg/l difference), whereas on 19 May 1998, the range was 14.5 to 0.8 mg/l (13.7 mg/l difference). The most rapid decline usually occurred between 1.5 and 2.0 meters depth. The oxygen content within one-meter of the bottom was less than 4.0 mg/l from June through August in 1997 and from mid-May through mid-October in 1998. The heavy layer of semi-decomposed organic matter on the bottom was probably the primary contributor to this hypoxia.

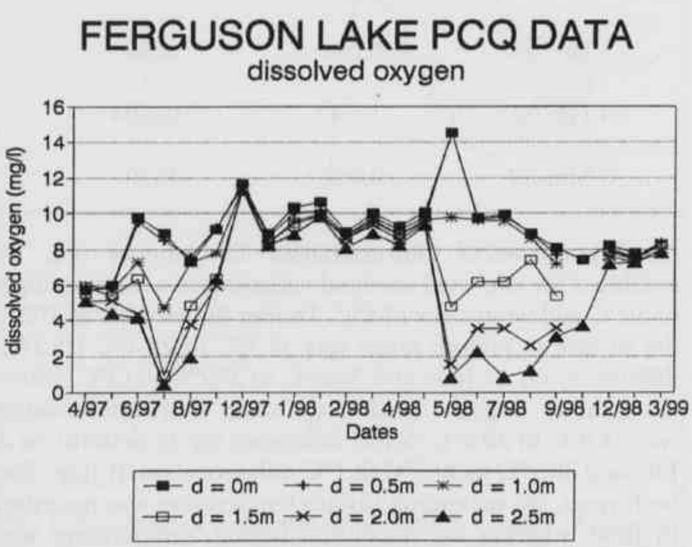

Fig. 3. Dissolved oxygen profiles in Ferguson Lake, April 1997-March 1999.

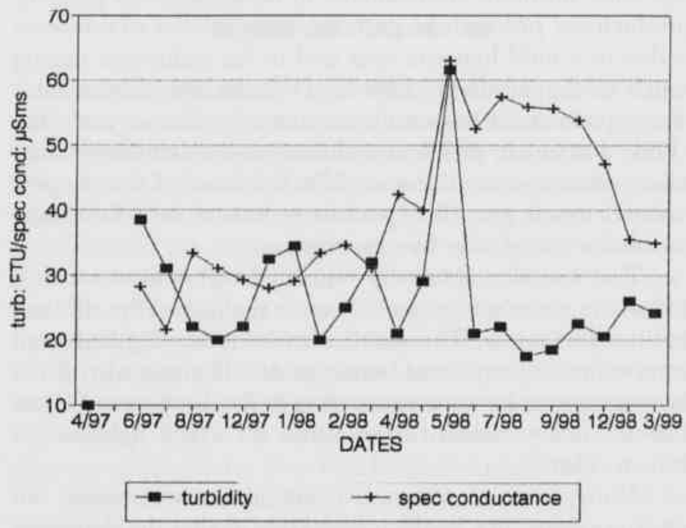

Fig. 4. Turbidity and specific conductance in Ferguson Lake, April 1997-March 1999.

Although the water was organically brown, the silt load, as indicated by turbidity, was relatively low (18-39 FTU) except for one sampling period (19 May 98: 62 FTU) which followed a heavy rain (Fig. 4). Specific conductance (Fig. 4) was also quite low (20-35 µSms), except for a high of 63 on the same date. Specific conductance exhibited a general but not consistent increase from mid-1997 to early fall 1998 then declined sharply from October 1998 to February 1999. Compared to other similar bodies of water, Ferguson Lake was quite low in electrolyte content.

Figure 5 shows pH and sulfate measurements. Excepting the period mid-May through mid-September 1998, pH ranged between 6.0 and 7.0. On 19 May 1998 pH spiked at 9.8 then steadily declined back to 6.1 on 4 February 1999. Sulfate readings varied erratically between zero and 2.5 mg/l for all but two sampling times (31 July and 20 August 1998) when the measurements were 4.5 and 3.5 mg/l, respectively. High sulfur content is certainly not a problem in the lake.

Alkalinity and hardness fluctuated randomly but in concert (Fig. 6). Most of the alkalinity measurements were between 10 and 27 mg/l (as $CaCO_3$), and hardness mostly ranged from 13 to 24 mg/l (as $CaCO_3$). Both variables exhibited a general decline from August 1997 to January 1998, a general rise from February to August 1998 and another

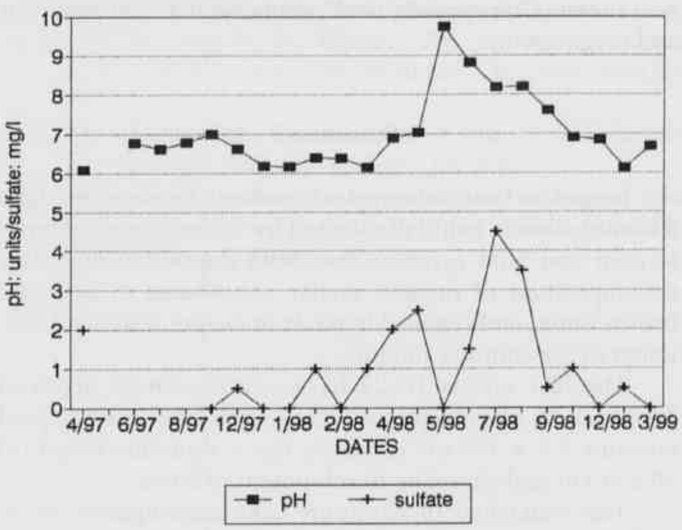

Fig. 5. pH and sulfate measurements in Ferguson Lake, April 1997-March 1999.

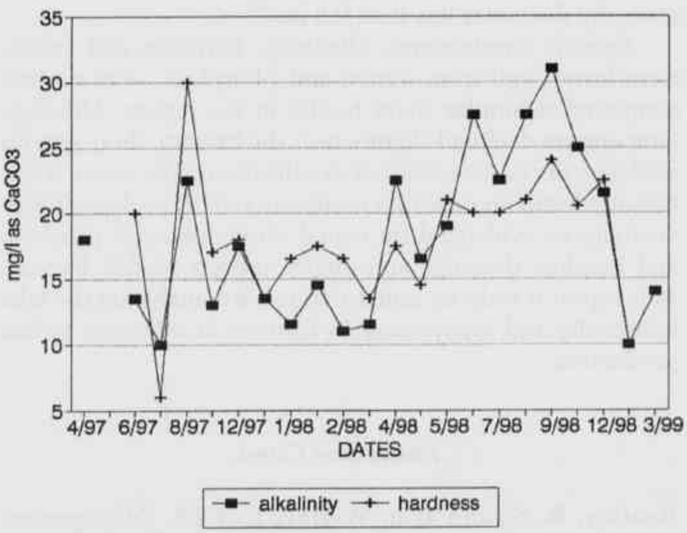

Fig. 6. Total alkalinity and total hardness measurements in Ferguson Lake, April 1997-March 1999.

decline until February 1999. The relatively low concentration of the anions OH^-, HCO_3^- and $CO_3^{=}$ (alkalinity) indicates a very low buffering capacity of the water. The lake would not be able to absorb a surge (spillage) of cations (for example, H^+, Na^+ or K^+). The low concentration of divalent cations Mg^{++}, Mn^{++}, Fe^{++} and Ca^{++} (hardness) indicates the water is "soft" (soap will lather easily), a characteristic that is of concern for snails (Mollusca:Gastropoda) and clams (Mollusca:Bivalvia) but has little effect on other organisms.

Nitrate-nitrogen (Fig. 7) fluctuated between a low of 0.08 mg/l (late winter) to prominent summer peaks of 1.2 mg/l (August 1997) and 1.05 mg/l (July 1998). Otherwise, sample-to-sample fluctuations were rather erratic. On 21 April 1998 fertilizer was applied aerially to the lake to enhance primary productivity, and the nitrate concentration increased from 0.15 mg/l to 0.25 mg/l within about two weeks, then declined back to 0.1 mg/l. Measurements further removed from the date of the application fluctuated (increased or decreased) much more. Except for the period 23 April to 19 May 1998, ortho-phosphate measurements varied randomly between 0.05 and 0.23 mg/l. Immediately following the fertilizer application, phosphate spiked to 1.21 mg/l but fell to its previous level (0.18-0.23 mg/1) almost as quickly (Fig. 7).

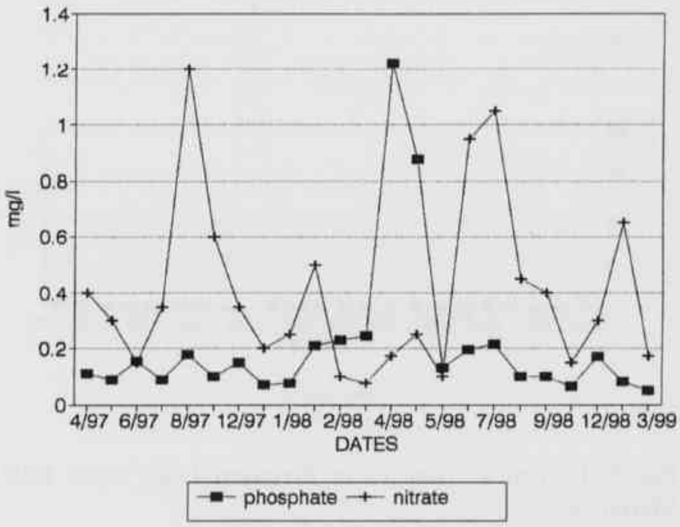

Fig. 7. Ortho-phosphate and nitrate-oxygen readings in Ferguson Lake, April 1997-March 1999.

Iron concentrations (Fig. 8) fluctuated lightly between 0.3 and 0.5 mg/l for the duration of the study period, except on 19 May 1998 when 39 mg/l was measured. Heavy rain had recently fallen in the watershed which would account for the unusually high peak and also for the quick decline of the phosphate after the fertilizer application.

From 1979 to 1989 Arkansas Power & Light Company (now Entergy Corporation) personnel conducted tests similar to ours on single samples taken every three months from Ferguson Lake. Our data varied from theirs in the following respects: (1) the older (AP&L) pH readings (mean = 6.298) were significantly ($P = 0.05$) lower than ours (mean = 6.996); (2) their phosphate (mean = 0.084 mg/l) and nitrate (mean = 0.148 mg/1) measurements were significantly (P = 0.05) lower than ours (means = 0.217 mg/l and 0.401 mg/l, respectively); (3) the older sulfate measurements (mean = 4.46 mg/l) were significantly (P = 0.05) higher than ours (mean 1.08 mg/l) ; (4) their iron readings (mean = 0.906 mg/l) were significantly (P = 0.05) higher than ours (mean = 0.504 mg/l); and (5) the older specific conductance measurements (mean = 35.1 uSms) were significantly (P = 0.05) lower than ours (mean = 40.4 uSms). Specific conductance readings in the older data exhibited cyclic variations, but they appeared to have a 15- or 16-month periodicity. Our data exhibited a strong "summer" peak in 1998 but not in 1997. Further data collection is necessary to verify this unusual cyclic periodicity.

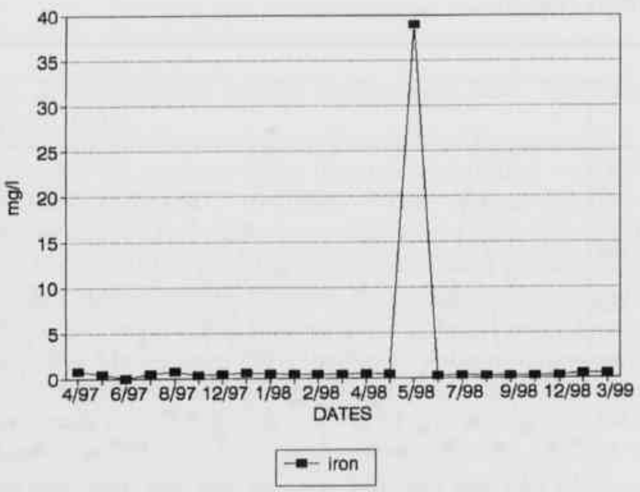

Fig. 8. Iron measurements in Ferguson Lake, April 1997-March 1999.

The observation that the concentrations of phosphate and nitrate seem to be increasing from the earlier study to ours suggests ongoing eutrophication of the water column. Such an increase would most likely stimulate higher rates of primary productivity, which, in turn, would gradually elevate the daytime pH as observed. The increase in conductance indicates an increase in electrolytes; predominantly cations such as Na^+, K^+, CA^{++}, Fe^{++}, and perhaps Mg^{++} and Mn^{++}. Our tests indicated iron decreased, but data for the other cations for both time periods are not available. AP&L personnel recorded 10 alkalinity measurements during the last three years of the earlier period which exhibited a mean of 7.13 mg/l (our mean was 18.4 mg/l). Usually alkalinity and hardness are related, and in natural waters both variables are likely to be high or both low. If hardness has increased similarly with alkalinity, then some of the increase in conductance would be identified, because hardness measures several divalent cations such as calcium, iron and magnesium.

Summary

Ferguson Lake is a typical lowland brownwater lake whose shallower half is dominated by a dense stand of tupelo gum and bald cypress. The rapid deposition and slow decomposition of organic matter contributes to low pH, brown water, and regional hypoxia in deeper water and sediment in the summer months.

The lake covers 171.22 ha, has a maximum depth of 4.27 m and a mean depth of 1.92 m. The lake's normal pool contains 3.3×10^6 m^3 of water, has a shoreline length of 10.235 km and shoreline development of 2.692.

The watershed of Ferguson Lake encompasses 58.56 km^2 and is mostly a forested lowland with an elevation gradient of 74.4 to 115.8 m(msl). The watershed to lake area ratio is 34.2 to 1. Heavy precipitation may cause rapid rises in the lake level, but spillway overflow is usually restricted to the period from November through June. Evaporation from the lake's surface is relatively rapid, but the water level normally fluctuates less than 0.5 m.

Specific conductance, alkalinity, hardness and sulfate were lower, and iron, nitrate and phosphate were normal compared to similar water bodies in the region. Although temperature declined slightly near the bottom, there was no evidence of classical thermal stratification. The water is sufficiently fertile to exhibit a moderate rate of ecological productivity as evidenced by casual observations of plankton and benthos densities and angler reports of fish harvest. This report is only an initial step toward analyzing the lake holistically and interpreting its features in reference to fish production.

Literature Cited

Beasley, R. S., and **T. B. Wigley, Jr.** 1988. Management alternatives for Ferguson Lake. Unpubl. Report to Lakeside Country Club Lake Preservation Committee, 24 Oct 1988, pp. 1-7 with appdx.

Brinson, M. M. 1977. Decomposition and nutrient exchange of litter in an alluvial swamp forest. Ecology 58:601-609.

Comer, W. H., and **J. W. Day.** 1991. Leaf litter decomposition in three Louisiana freshwater forested wetland areas with different flooding regimes. Wetlands 11: 303-312.

Harper, C. A., and **E. G. Bolen.** 1995. Leaf-litter decomposition in blackwater impoundments. J. Freshw. Ecol. 10(2):193-195.

Horne, A. J., and **C. R. Goldman.** 1994. Limnology, 2nd ed. McGraw-Hill, Inc., New York, pp. 420,1.

Reid, G. K., and **R. D. Wood.** 1976. Ecology of inland waters and estuaries. Van Nostrand Co., New York, p. 90.

Rice, K. D., and **M. Rooker.** n.d. A history of Lakeside Country Club. Unpubl. mimeo., pp. 3-8.

Standard Methods for the Examination of Water and Wastewater, 16th ed., 1985. Publ. by APHA, AWWA, and WPCA, pp. 210ff and 269ff.